Study the Effect of Co-Channel Interference in STC MIMO-OFDM System and Mitigation of CCI using Beamforming Technique

A Thesis
Submitted in Partial Fulfillment of the
Requirements for the Award of the Degree of

Master of Technology
In
Electronic systems and communication

By
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CERTIFICATE

This is to certify that the Thesis Report entitled "**Study the Effect of Co-Channel Interference in STC MIMO-OFDM System and Mitigation of CCI using Beamforming Technique**", submitted by **Mr. Subhankar Chakrabarti,**bearing roll no. **211EE1115** in partial fulfillment of the requirements for the award of Master of Technology in **Electrical Engineering** with specialization in "**Electronic systems and communication**" during session 2011-2013 at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any Degree or Diploma.

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NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA

DECLARATION

I hereby declare that this thesis entitled "**Study the Effect of Co-Channel Interference in STC MIMO-OFDM System and Mitigation of CCI using Beamforming Technique**" submitted to National Institute of Technology, Rourkela for the award of the degree of Master of Technology is a record of original work done by me under the guidance of Prof. Susmita Das and that it has not been submitted anywhere for any award. Where other sources of information have been used they have been acknowledged.

Subhankar Chakrabarti

Date:
Place:

ACKNOWLEDGEMENTS

This project is by far the most significant accomplishment in my life and it would be impossible without people who supported me and believed in me.

First mostly, I would like to extend my gratitude and my sincere thanks to my honorable, esteemed supervisor Prof. Susmita Das, Department of Electrical Engineering. She is a great lecturer with deep vision and also most importantly a kind person. I sincerely thank her for exemplary guidance and encouragement. Her trust and support inspired me in the most important moments of making right decisions and I am glad to work under her supervision.

I am very much thankful to our Head of the Department, Prof. A.K.Panda, for providing us with best facilities in the department and his timely suggestions. I am very much thankful to all my teachers Prof. Dipti Patra, Prof. K. R. Subhashini, Prof. P.K. Sahu, and Prof. S.Gupta for providing a solid background for my studies and also my sincere thanks to Mr.Kala Praveen Bagadi, Mr. Kiran Kumar Gurrala and Mr.Deepak Kr. Rout for giving encouragement, help and planning to carry out the entire work. They have been great sources of inspiration to me and I thank them from the bottom of my heart.

I would like to thank all those who made my stay in Rourkela an unforgettable and rewarding experience.

Last but not least I would like to thank my parents and sister, who taught me value of hard work by their own example. They rendered me enormous support being apart during the whole tenure of my stay in NIT Rourkela.

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List of contents

ABSTRACT

In this modern age of high speed wireless data communication, Multiple input multiple output orthogonal frequency division multiplexing (MIMO-OFDM) schemes have recently drawn wide interests due to their capability of high data rate transmission over multipath fading channels. This thesis work introduces the study of multi- user and multi-antenna MIMO-OFDM systems. In this work, the performances of two main classes of MIMO-OFM system i.e. multi-user and multi-antenna MIMO-ODM techniques have been studied. The transmitted data is sent using BPSK, QPSK modulation techniques. The performance of the system in Rayleigh and AWGN channel is studied. Space time coding technique also used in transmitting side of the multi-antenna MIMO system.Study and analysis of the effect of co-channel interference over wireless communication system is considered the main objective of this project work .Beamforming technique is one of the best techniques to mitigate co-channel interference. There are several beamforming techniques like LMS, RLS style beamforming techniques. LMS style adaptive beamforming technique is applied to the system. The performance of the LMS style beamforming technique for mitigation of co-channel interference has been analyzed for different modulation techniques.The performance comparison between the adaptive beamforming and null steering beamforming techniques is carried out for the space time coded MIMO-OFDM system. From the performance analysis, it is observed that to mitigate the co-channel interference in ST coded MIMO-OFDM system, adaptive beamforming technique outperforms the method based on the null steering beamforming.

Key Words: MIMO, OFDM, Space Time Code, Beamforming

List of Figures

List of Tables

Acronyms and abbreviations

STBC	Space time block code
OFDM	Orthogonal Frequency Division Multiplexing
AWGN	Additive White Gaussian Noise
STC	Space Time Code
MIMO	Multi Input Multi Output
CSI	Channel State Information
SDMA	Space Division Multiple Access
CIR	Channel Impulse Response
STTC	Space Time Trellis Code
SDM	Space Division Multiplexing
BER	Bit Error Rate
ML	Maximum Likelihood
CCI	Co-Channel Interference
LMS	Least Mean Square
SIR	Signal to Interference Ratio

CHAPTER 1

INTRODUCTION

1.1 Introduction and Literature survey

Progressive and perfect transmission of multimedia data over wireless fading channels in the design of efficient wireless communication systems has attracted a lot of interests due to increased demand for wireless applications throughout the world. The transmitted data is interfered by channel noise, co-channel interference when transmitted, and these noises and CCI affect randomly and suddenly on all transmission bits. Diversity techniques, including spatial, frequency, and time domain diversity, have been suggested to decrease the channel fading effect. There are many techniques and algorithms to mitigate the CCI effect also [3]. Sufficiently spaced antennas are an attractive source of diversity since they do not typically incur in bandwidth expansion as in frequency division diversity, and does not incur delays as in time diversity. Though spatial diversity is available at transmitter and receiver, it may not be possible to get much diversity gain at mobile terminal because of the limitations in space and power. We consider using space time block codes (STBC) [8] ,spatial diversity technique to decrease fading effects in both time and frequency domain for orthogonal frequency division multiplexing (OFDM) systems . In order to overcome channel interference, efficient channel error correcting coding also necessary.

Space time code [8],[9] is very effective coding technique designed for multiple antenna transmission. With the diversity improvement on fading channels, it can achieve a coding gain without bandwidth sacrifice. Combinations of multiple receive antennas and space-time coding can minimize the effects of the multipath fading and can achieve high channel capacities in the MIMO (multiple-input multiple-output) systems [13]. Now, there has been very much interest for high speed data services such as image transmission, video conferencing, internet access over wireless channels. Thus, the channel introduces inter-symbol interference (ISI),co-channel interference which makes the system performance degrade. Without equalization, a promising approach to minimizing ISI is OFDM technique [16] which is used in various standards of wireless communication systems. The high rate data stream is divided into a large number of parallel sub-channels. The number must be chosen to ensure that each subchannel has a bandwidth less than the coherence bandwidth of the channel, so the subchannel is categorized as flat fading. Each sub-channel however has an error probability in deep fades.

The combination of space-time coding and the OFDM modulation technique [17] is not only minimize drawbacks of each other, but also improve the high speed transmission performance limited to multipath fading and ISI. However, using multiple transmit antennas at each mobile introduces mutual interference at the receiver by either signals transmitted from different antennas of the same transmitter or other transmitters. Additional processing is required to mitigate co-channel interferences (CCI) in space-time coded OFDM (STC-OFDM) systems.

Adaptive antenna arrays are an attractive solution as they can suppress CCI and mitigate the effects of multipath fading [19], [20], [21]. Study on receive beamforming which is applied to uplink of cellular mobile systems has also attracted attention to both suppress CCI and minimize fading effects. The scheme of MIMO wireless systems incorporating an beamforming method before space-time decoder can effectively mitigate CCI while preserving the space-time structure. The beamforming method called the minimum variance distortion response (MVDR) beamformer is used as a CCI canceller in OFDM systems using space-time codes in reverse link. Adaptive beamforming technique and null steering beamforming technique is also very effective for mitigation of co-channel interference.

1.2 Motivation to MIMO systems

During past few years, multimedia wireless communication has changed and benefitted from several advances in various directions and it is considered as an important enabling technique of innovative and complex future consumer products. Significant technological achievements are required for the sake of satisfying the requirements of various applications and to ensure that wireless devices suitable for supporting a wide range of services have appropriate architectures delivered to the users.

In the foreseeable future, tremendous new challenges in terms of the efficient exploitation of the achievable spectral resources are expected to lead for the requirements of high bandwidth applications in the large scale deployment of wireless devices. New wireless techniques, such as ultra wideband (UWB), advanced channel and source coding as well as various smart antenna techniques, for example space-time codes [1], space division multiple access (SDMA) and beam forming, as well as other MIMO wireless architectures are capable of offering substantial gains.

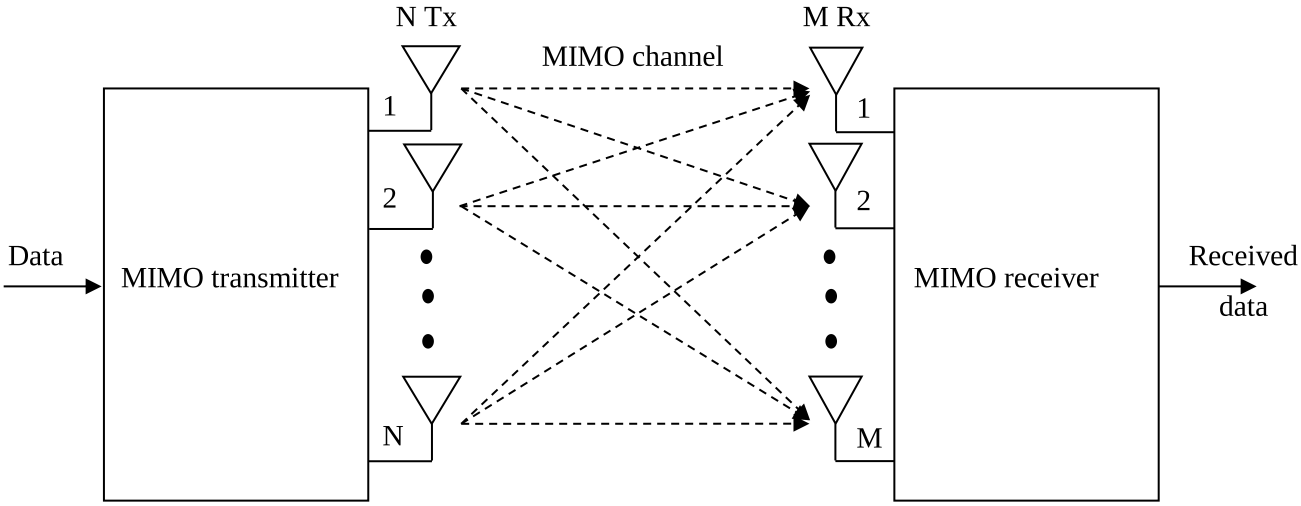

Figure 1.1 *Schematic of the generic MIMO system employing N transmitter antennas and M receiver antennas[4]*

Now, most of the research works have concentrated on the next generation of high speed wireless broadband communication systems, which target for high data rates in multimedia internet and telephone services. Undoubtedly, to maintain a high robustness against radio channel impairments with support of such high data rates requires further enhanced system architectures, which should aim for approaching the capacity of MIMO-aided systems communicating over wireless fading channels. Conceptually, in the wireless channels, we argue that the one transmitter (1 Tx) and one receiver (1 Rx) scenario is exposed to fading, since the vectorial sum of the multiple propagation paths may add constructively or destructively. In contrast, as an example, the chances are that at least one of the independently faded diversity links benefits from the constructive interference of the received paths for the 2 Tx and 4 Rx scenario.

Various smart antenna designs have emerged in recent years, which have found application in diverse scenarios and four most famous MIMO types are briefly listed and described in Table 1.1.

The four MIMO systems were designed for achieving various design goals. The family of SDM schemes target for maximizing the attainable multiplexing gain i.e., the throughput of a single user by exploiting the distinctive, antenna definite channel impulse responses (CIRs) of the array elements. By contrast, SDM schemes are closely related to the SDMA arrangements, as opposed to maximizing the throughput of a single user by sharing the entire system throughput amongst the users supported. Then again, the families of STBC as well as space time trellis coding (STTC) schemes aims to attain the maximum possible diversity gain. Finally beam forming mitigates the effects of interfering users when their received signals are angularly separable.

Table 1.1 *The four Main Applications of MIMO in Wireless Communications*

Space division multiplexing (SDM)	The main aim for incorporating this system is to maximize the throughput of a single user using unique channel impulse response (CIR).
Space division multiple access(SDMA)	This scheme maximizes the number of users supported as opposed to maximizing the throughput of a single user.
Spatial diversity	Main objective of this scheme is to attain the maximum diversity gain. STBC, STTC are the different Space Time Coding techniques, part of Spatial diversity scheme, and provide the diversity gain.
Beam forming	This scheme is used to mitigate the effect of CCI provided that the signals from the antenna are angularly separable.

The basic principle of OFDM invented over the years ago, many researchers has investigated this technique to make use of costly bandwidth effectively. Due to implementation difficulties, the OFDM employment has mostly limited to military applications. However, it has recently been implemented in digital audio broadcasting (DAB) standard as well as the digital video broadcasting (DVB) and for a range of other high speed applications, such as Wireless local area networks (WLANs). These wide ranging applications resemble its significance as an alternative technique to traditional channel equalization in order to combat signal dispersion.

1.3 Thesis objective

The objective of this work is to study and analyze the performance of the multi-user and multi-antenna MIMO-OFDM communication system. The combination of MIMO system and OFDM schemes play a very important role in modern high speed communication system. The effect of co-channel effect on Space Time Coded MIMO-OFDM system will be studied. Along with this work, the performance of the LMS style beamforming technique which is very effective technique to mitigate the co-channel interference will also be analyzed. The comparison between the performance of adaptive beamforming and null steering beamforming will also be analyzed.

1.4 Thesis organization

- Chapter1 introduces the basic motivation behind this project work and describes the literature survey. In literature survey, we discussed the MIMO technique and its applications in the wireless communications. Also we have seen the objective of our work.
- Chapter2 introduces basic concepts of MIMO-OFDM systems. Also we will see the various advances that took place in OFDM with ages. This chapter deals with the advantages of the combination of MIMO OFDM system.
- Chapter3 describes about Multi-Antenna MIMO-OFDM communication system. We also discussed about some single user multiple antenna technique like BLAST technique. We also discussed about the space time coding technique. It also introduces the multi-user MIMO-OFDM communication system. The basic concept of Space Division Multiplexing Access also discussed in this chapter.
- Chapter4 discusses the effect of co-channel interference in MIMO-OFDM communication system. We also discussed the basic concept of beamforming technique to mitigate the co-channel effect.
- Chapter5 discusses the simulation result with the details of the simulation parameters.
- Chapter6 draws the conclusion and discusses the future work.

CHAPTER 2

BASIC MIMO-OFDM CONCEPTS

2.1Introduction

This chapter introduces the basics of OFDM technique that is used in our proposed system. Here we discussed all the developments of OFDM and the fundamental structure and merits, demerits of the technique. Further, this chapter tells the way it saves the bandwidth and the how an OFDM symbol looks like. This also gives the base band OFDM structure with all necessary equations.

Also we have given the basic concepts of combined MIMO OFDM system and also its description for implementation.

In sequence, this chapter describes all the spatial diversity schemes such as Alamouti transmit diversity scheme, maximal ratio combining and the second order diversity schemes used in the classical and proposed system for evaluation. Here we have given all essential equations of the combining schemes at the receiver end for detection.

2.2 Orthogonal frequency division multiplexing Technique

OFDM is a very popular multi carrier modulation cum multiplexing technique for transmission of signals over wireless fading channels. It converts a frequency selective fading channel into a collection of flat parallel fading sub channels, which mostly simplifies the structure of the receiver. Even though the signal spectra related to different subcarriers overlap in frequency domain but the time domain wave form of the subcarriers are orthogonal. So that the available bandwidth is used efficiently in OFDM systems without the inter carrier interference. OFDM systems can provide a high data rate with long symbol duration by mixing up multiple low data rate sub carriers with long symbol duration. That helps to avoid the inter symbol interference (ISI), which occurs along with signals of a short symbol duration in a multipath channel of MIMO-OFDM communication system. Here we are listing some major merits and demerits of the scheme as follows.

Merits of OFDM systems are:

- ❖ Spectral efficiency is high.
- ❖ Fast Fourier transform (FFT) implementation makes less complex.
- ❖ Complexity is very low at the receiver.

- This scheme is robust for high data rate transmission over multipath fading channel
- In terms of link adaptation this is highly flexible
- Orthogonal frequency division multiple access is low complexity multiple access scheme

Demerits of OFDM systems are:

- Sensitive to phase noise, frequency offsets and timing errors
- Relatively high peak to average power ratio compared to single carrier system, which tends to reduce the power efficiency of the RF amplifier

Though the developments of OFDM technology, there are two considerable contributions to OFDM which transform the original “analog” multicarrier system to today’s digitally implemented OFDM. For the implementation of OFDM systems the use of Discrete Fourier Transform (DFT) decreased to perform baseband modulation and demodulation which was eliminated the banks of coherent demodulators and sub carrier oscillators required by frequency division multiplexing. DFT based frequency division multiplexing can be fully implemented in digital baseband. FFT for highly efficient processing, a fast algorithm for computing DFT, can even further reduce the number of arithmetic operations to $N\log N$ from N^2 (N if FFT size).

A guard interval can be used in between consecutive symbols and the raised cosine windowing in the time domain to combat the ISI and the ICI. But over a time dispersive channel the system could not maintain perfect orthogonality between subcarriers. This problem was tackled with the use of cyclic prefix (CP) or cyclic extension. Here they replaced the guard interval with a cyclic extension of the OFDM symbol. The ISI can be eliminated totally if the length of cyclic extension is longer than impulse response of the channel. Further, this scheme well simulates a channel performing cyclic convolution which ensures the orthogonality between subcarriers over a time dispersive channel. The principle of OFDM system is to divide a single high data rate bit stream into a number of lower data rate bit streams those are transmitted over narrower sub channels simultaneously. So it is a modulation (frequency modulation) technique and also a multiplexing (frequency division multiplexing) technique. The difference between OFDM and conventional FDM is shown in figure 2.1.

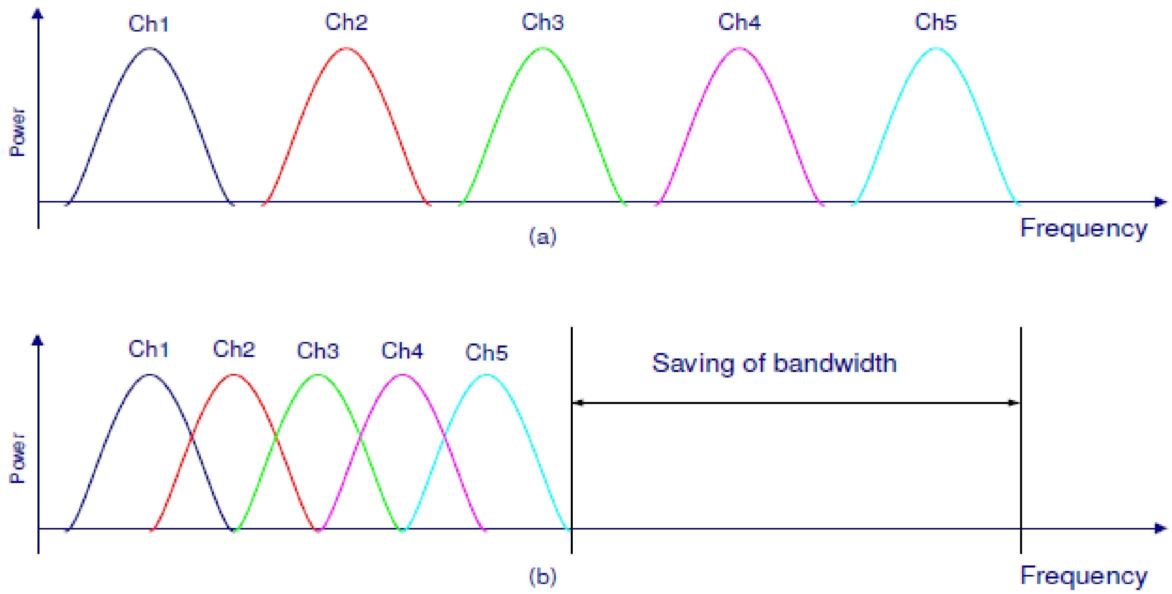

Figure 2.1 *Comparison between conventional FDM and OFDM [4]*

As shown in figure, in order to implement this conventional parallel data transmission using FDM technique a guard band have to be introduced between subcarriers to overcome the inter channel interference. This shows that the expensive and rare spectrum resource is used inefficiently. In the mid of 1960s, researchers investigated for an FDM system with overlapping multicarrier modulation. To realize this scheme, however we need to get rid of the ICI, which tells that we have to maintain orthogonality perfectly between the different modulated carriers. The specific mathematical relationship between the frequencies of the different subcarriers of the system is shown by orthogonality. In this OFDM scheme, assume that the OFDM symbol period is T_s with the minimum spacing between subcarriers is $1/T_s$. With this specific constraint, the integration of the product of anyone of the sub carriers (f_s) over one symbol period T_s and the received signal will extract the subcarrier f_s only, since the integration of the product of any other subcarriers over T_s and f_s results zero. This overcomes ICI in the OFDM scheme while achieving almost 50% bandwidth savings. The concept of OFDM in the sense of multiplexing is illustrated in the figure2.2.

In every T_s seconds, a total of N complex valued numbers from different phase shift keying or quadrature amplitude modulation (PSK/QAM) constellation points are used to modulate N different complex carriers centered at f_k, $1 \le k \le N$. This composite signal is obtained by summing up all the N modulated carriers.

The usage of inverse fast Fourier transform (IFFT), instead of local oscillators, was a significant breakthrough in the OFDM system. This is a crucial part for OFDM system. It transforms data from frequency domain to time domain.

The baseband OFDM system is as shown in the figure 2.3**,** where t_k is the transmitted symbol, *h(t)* represents the channel impulse response, *n(t)* gives the white complex Gaussian channel noise and r_k is the received symbol.

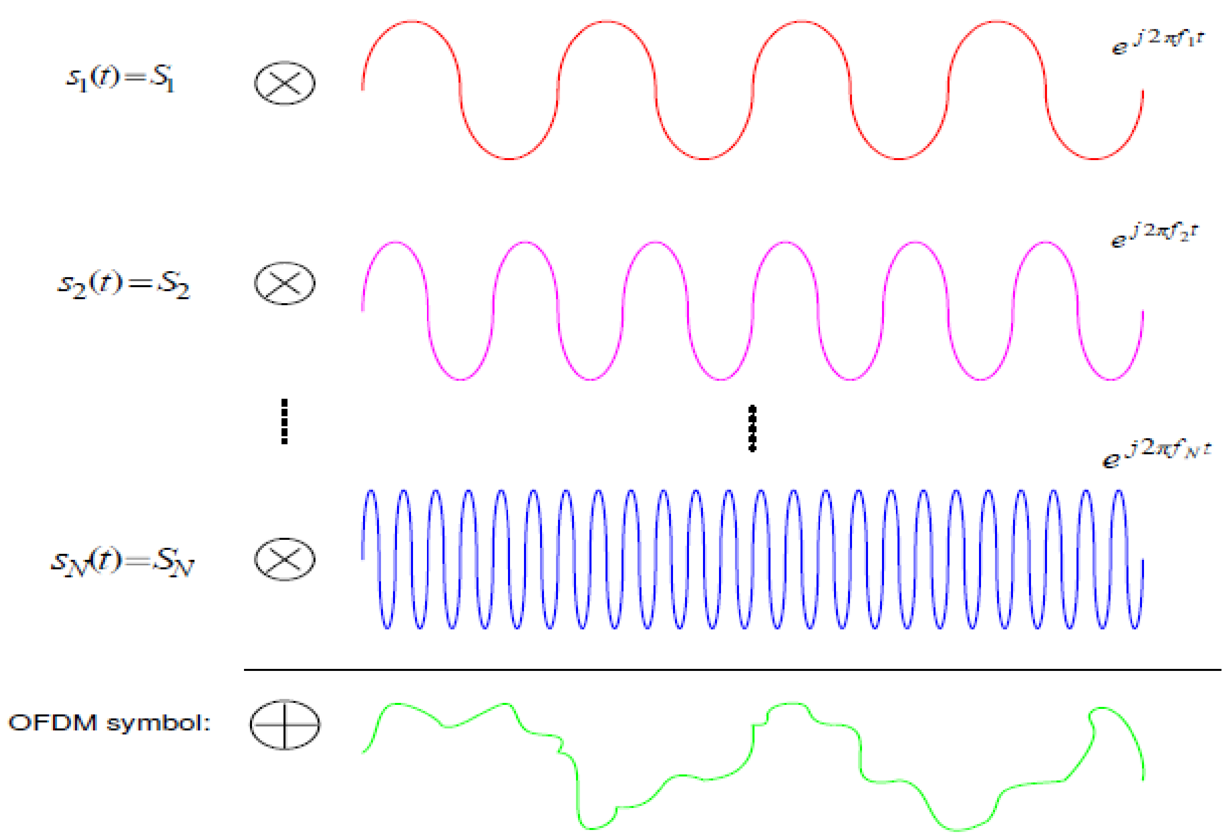

Figure 2.2 *OFDM concept graphical interpretations[6]*

The t_k s are taken from a M-ary signal constellation. The A/D and D/A converters contain ideal LPF (low pass filters) with $1/T_s$ band width, where sampling interval is T_s**.** The channel impulse response is a time limited pulse of the form

$$h(t,\tau)=\sum_{n=1}^{N}\alpha_n(t)\delta(\tau-\tau_n) \tag{2.1}$$

Where N gives the number of available paths between transmitter and receiver; where each path is a complex Gaussian process with zero mean and variance. Here, The path delay satisfies $\tau \leq T_g$ i.e., the guard space incudes the entire impulse response. The normalized channel response is

$$\sum_{n=1}^{N}\sigma_n^2=1$$

Using eq. 2.1**,** at time t time varying channel frequency response given as

$$H(t,f)=\int_{-\infty}^{\infty}h(t,\tau)e^{-j2\pi f\tau d\tau}=\sum_{n=1}^{N}\alpha_n(t)e^{-j2\pi f\tau} \tag{2.2}$$

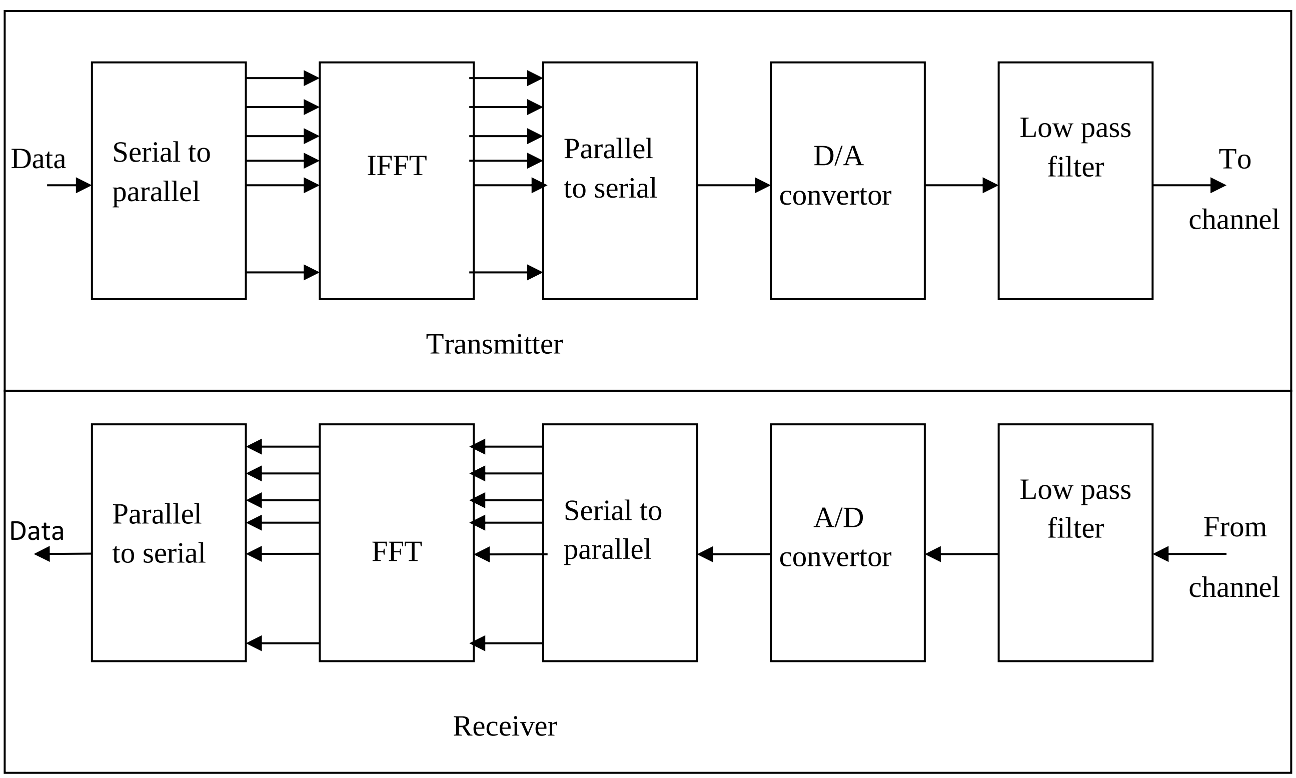

Figure 2.3 *Base band OFDM system[4]*

For an OFDM system with block length and sub channel spacing (tone spacing) Δf, after FFT the output signal at the *q* th tone of the p th OFDM block can be represented as

$$y[p,q] = H[p,q]x[p,q] + n[p,q] \tag{2.3}$$

Where $n[p, q]$ is additive Gaussian noise at the *q* th tone and the *p* th block, with zero mean and variance σ^2**.** We also assume that $n\,[p, q]$ is independent for different *p* 's, *q* 's. $H[p, q]$ is the frequency response at the *q* th tone of the *p* th block.

2.3 Combined MIMO-OFDM systems

High data rate wireless multimedia communications have attracted significant interest and represent an extensive research challenge in the context of indoor multimedia networks and the WLANs. MIMO technique referred as specifically implementation of multiple antennas at both the transmitter and the receiver, results a cost effective approach to high throughput and high speed wireless communications.

The MIMO concepts [10] for wired and wireless systems have been under development for many years. In mid 1980s, when Winters [11], published a number of breakthrough contributions, where he introduced a technique using multiple antennas at both transmitter and receiver ends to transmit data from multiple users over the same frequency time channel. Later joint transmitter receiver optimization using the minimum mean square error (MMSE) criterion investigated. MIMO system is capable of exploiting transmitter and receiver diversity, since the information is transmitted through different paths, hence maintaining reliable communications. Even more, it becomes possible to jointly process/combine the multi antenna signals and thus improves the system's throughput, with the advent of multi antenna signals.

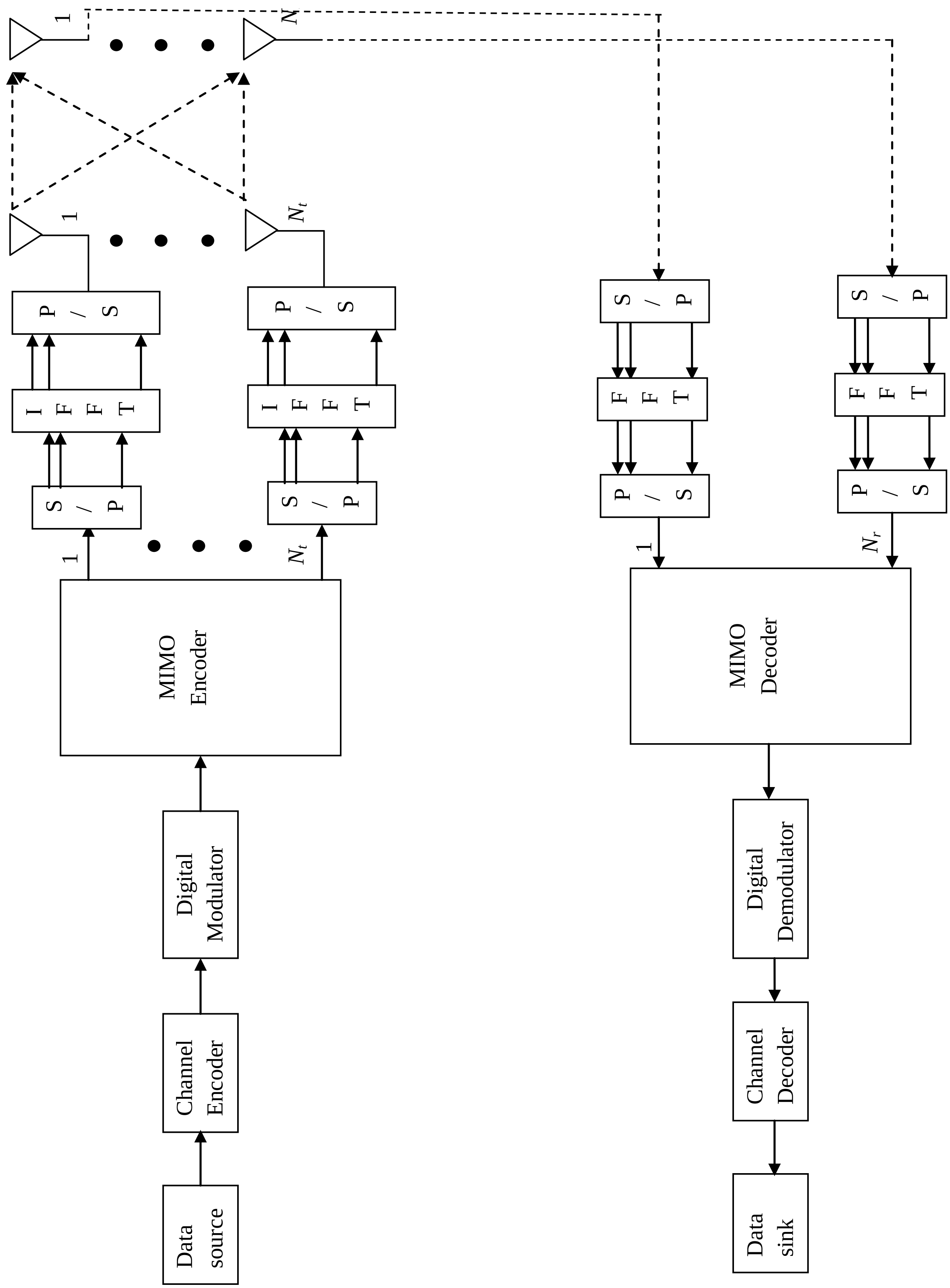

Figure 2.4 *MIMO-OFDM structure[6]*

Significant increase achieved in terms of both spectral efficiency and system's capacity. With the minimum of the transmitter and receiver antennas in any communication system, the capacity of a wireless link increases linearly. The data rate of any communication system can be increased by spatial multiplexing, without increasing the total transmitted power and without consuming more frequency resources. Significant reduction of the fading effects observed due to increased diversity. This is specifically beneficial, when the different channels fade independently.

The transmission rate, the transmission range and the transmission reliability are the three basic parameters which describes the quality of the wireless communication link. By reducing the transmission range and reliability may be increases the transmission rate. In contrast, at the cost of lower transmission rate and reliability, the transmission range may be extended. However, the above mentioned three parameters may be simultaneously improved with the use of MIMO assisted OFDM systems. With the aid of MIMO techniques, it is shown that an increased capacity, coverage and reliability achieved in broadband wireless MIMO OFDM communication systems. Furthermore, any modulation or multiple access techniques can potentially be combined with MIMOs, recent research suggests that the implementation of MIMO aided OFDM is more efficient, as a benefit of the straight forward matrix algebra invoked for processing the MIMO OFDM signals.

2.4 Conclusion

Here we can conclude that this combination of MIMO OFDM system is one of the effective ways to combat the fading effect of the channel and to conserve the bandwidth. Further, we can say that the spatial diversity schemes are plays major role in retaining the data quality at the receiver end from channel interference.

Also we dealt with the basic concepts of combined MIMO OFDM system and also its description for implementation and the advantages of the combination.

CHAPTER 3

MULTI-USER AND MULTI-ANTENNA MIMO-OFDM TECHNIQUE

3.1 Introduction

In this chapter we introduce Multi-Antenna MIMO-OFDM technique which plays a great role in wireless communication system. We will discuss about different single user multi antenna techniques like BLAST, PARC and SPARC.

We will also discuss about space time coding which is used in multi antenna MIMO-OFDM scheme to uncorrelate the transmitted data from multiple antennas of single user. The STC-OFDM MIMO system model which can be an effective system model for high speed communication system will also be introduced in this chapter.

3.2 Multi-User MIMO-OFDM Communication System

The multi-user MIMO-OFDM system has great potential of providing enormous capacity due to its integrated space-frequency diversity and multi-user diversity. Assuming knowledge of the channel state information (CSI) at the transmitter, significant performance gain can be obtained by efficiently adjusting each user's transmission power and rate on different subcarriers.

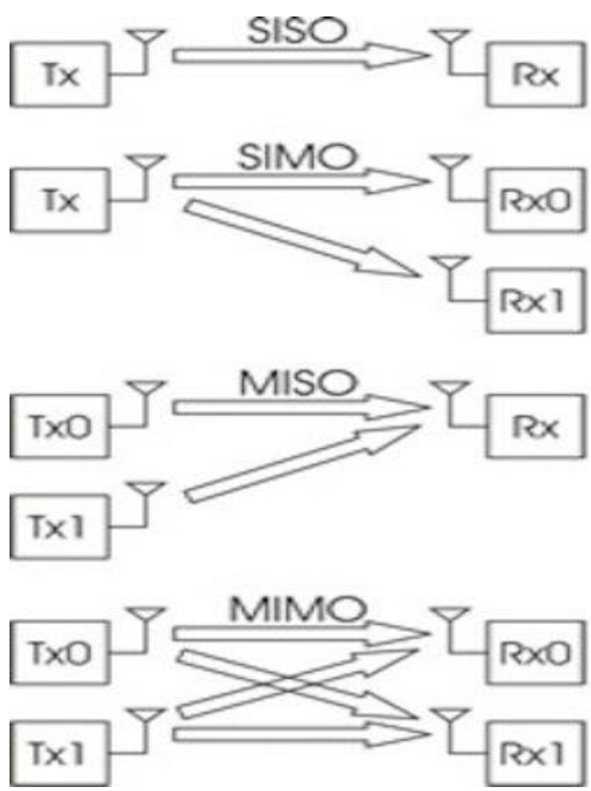

Figure 3.1 *Transformation of SISO system to MIMO System [4]*

Many multiplexing techniques like TDMA,FDMA,SDMA are used to transmit data from Multiple User through channel in case of MIMO-OFDM wireless communication systems. multiuser MIMO systems are largely unexplored. Making progress in the area of multiuser MIMO systems is of key importance to the development of practical systems that exploit MIMO gains on the system level also. The recently launched EU FP6 STREP project Multiple-Access Space-Time Coding Testbed (MASCOT) is aimed at developing, analyzing, and implementing (in hardware) concepts and techniques for multiuser MIMO communications. Specific areas of relevance in the context of multiuser MIMO systems include multiple-access schemes, transceiver design and space-frequency code design. In particular, the variable amount of collision-based framework for multiple access, , needs to be further developed to account for the presence of out-of-cell interference and to allow for variable amounts of collision in space, time, and frequency [1].

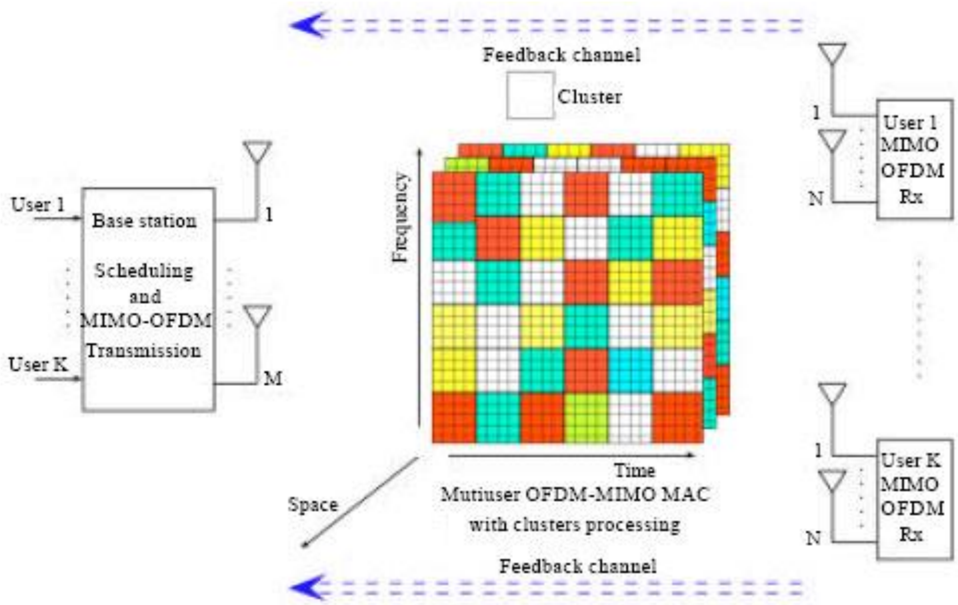

Figure 3.2 *Block Diagram for Multi-User MIMO-OFDM System [7]*

3.3 Single User Multi-Antenna Technique

The role of MIMO systems in the development of such future high-speed wireless networks is likely to be very important as these can not only establish extremely high data rate point-to-point links in a network but also increase the overall system users (in turn the system capacity). The basic idea behind these MIMO systems is the deployment of multiple antennas at one or both ends of a communication link, use of appropriate detection algorithm at the receiver end, and exploitation of multipath scattering which is a common phenomenon in any wireless channel, instead of its mitigation as is done in conventional wireless systems based on FDM, TDM, and CDM [2]. There are mainly three single user multi antenna technique like BLAST,PARC and SPARC techniques.

3.3.1 BLAST Technique

Bell Lab's mobile network innovation, called BLAST (Bell Labs Layered Space Time), uses multiple antennas at the terminal and base station to send and receive wireless signals at ultra-high speeds. When utilized in base station equipment and mobile devices, it permits higher-speed mobile data connections for notebook PCs and handheld data devices such as personal digital assistants. This will enable mobile operators to provide higher-quality, higher-speed data services that are possible with the best 3G network technology available today.

BLAST technology essentially exploits a theoretical concept that many researchers believed was impossible. In most wireless environments, radio signals do not travel directly from transmitter to receiver, but are randomly scattered in transit before they reach the receiver. The prevailing view was that to have good reception, each of these signals needed to occupy a separate frequency, similar to the way in which radio or TV stations within a geographical area are allocated separate frequencies. Otherwise, the interference between stations operating on the same frequency would be too overwhelming to achieve quality communications.

Its spectral efficiency ranges from 20 to 40 bps/Hz while efficiency of traditional wireless communication techniques ranges from 1 to 5 bps/Hz(mobile cellular) to around 10 to 12 bps/Hz (point to point fixed microwave system) [2].

There are other techniques also like Per Antenna Rate Control (PARC), Selective Per Antenna Rate Control (SPARC) which are used as popular Single User Multi-Antenna MIMO-OFDM technology in wireless communication system.

3.4 Space Time Coding Technique

Space-time Code which is a very effective method, to improve the reliability and efficiency of data transmission in high speed wireless communication systems using multiple transmit antennas,. To allow reliable and perfect decoding, Space Time Codes are based on transmitting multiple, redundant copies of a data stream to the receiver in the hope that at least some of the data may survive in the physical path of the wireless communication system between transmission and reception in a good enough state.

Space time codes may be divided into two main types:

- Space–time trellis codes (STTCs) distribute a trellis code on convolutional code over multiple antennas and multiple time-slots and provide both coding gain and diversity gain to the communication system.
- Space–time block codes (STBCs) act on a block of data at once (similarly to block codes) and also provide coding gain and diversity gain.

Space Time code may be further subdivided according to whether the receiver knows the channel information. In coherent STC, the receiver knows the channel statistics through training or some other forms of estimation.

The statistics of the channel is known by the receiver in non-coherent STC method but the receiver does not know the channel information. In differential space–time codes the channel and the statistics of the channel both are unavailable.

3.4.1 Alamouti transmit diversity scheme

Two branch transmit diversity scheme base band representation is shown in figure 2.6.

Two signals are transmitted at the same time or simultaneously from the two antennas at a given symbol period. Let the signals s_0, s_1 are transmitted from antenna zero and one respectively. During the next symbol period signal (s_0*) is transmitted from antenna one, and signal ($-s_1$*) is transmitted from antenna zero where * is the operation of complex conjugate. This sequence is shown in table 2.1.

In table 2.1, the encoding is done in space and time (space time coding).Two adjacent carriers may be used in in space frequency coding method, instead of two adjacent symbol periods.

Table 3.1 *The Encoding and transmission sequence for the two branch transmit diversity scheme*

	Antenna 0	Antenna 1
Time *t*	s_0	s_1

Time $t + T$	$-s_1*$	s_0*

At time t the channel may be modeled as a complex multiplicative distortion $h_0(t)$ for transmitting antenna zero and $h_1(t)$ for transmitting antenna one. Assuming that constant fading across two consecutive symbols, we can write

$$h_0(t) = h_0(t+T) = h_0 = \beta_0 e^{j\theta_0} \quad \text{and} \quad h_1(t) = h_1(t+T) = h_1 = \beta_1 e^{j\theta_1} \tag{3.1}$$

Where symbol duration is T.

Then the received signals can be expressed as

$$r_0 = r(t) = h_0 s_0 + h_1 s_1 + n_0 \quad \text{and} \quad r_1 = r(t+T) = -h_0 s_1^* + h_1 s_0^* + n_0 \tag{3.2}$$

Where the received signals at time t and $t + T$ are $r_{0,}$ r_1 and n_0 , n_1 are complex random variables representing receiver noise and interference.

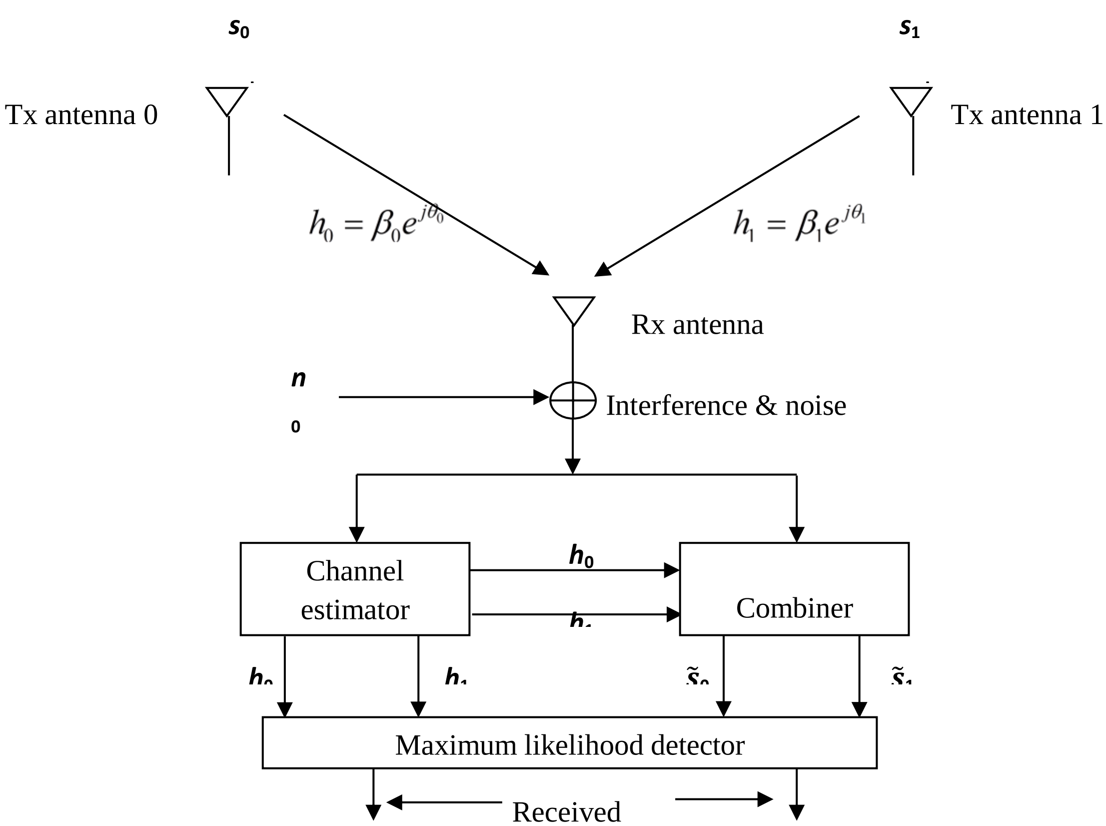

Fig 3.3 *Alamouti transmit diversity scheme[8]*

The combining scheme: The combiner shown in fig. 4.1 builds the following two combined signals that are sent to the maximum likelihood detector:

$$\tilde{s}_0 = h_0^* r_0 + h_1 r_1^*$$
$$\tilde{s}_1 = h_1^* r_0 - h_0 r_1^* \qquad (3.3)$$

Here this combining scheme is different from the maximal receiver ratio combining in (2.10). Substituting (4.1) and (4.2), into (4.3) we get

$$\tilde{s}_0 = (\beta_0^2 + \beta_1^2)s0 + h_0^* n_0 + h_1 n_1^* \quad \text{and} \quad \tilde{s}_1 = (\beta_0^2 + \beta_1^2)s_1 - h_0 n_1^* + h_1^* n_0 \qquad (3.4)$$

The resulted combined signals in (4.4) are similar to that of two branch MRRC. The effective SNR is not minimized, due to the only difference is in phase rotations on the noise components. So from this we say that the resulting diversity order from the new two branches transmit diversity scheme with one only one receiver is equivalent to that of two branch MRRC.

3.4.2 Two branch transmit diversity with two receivers

The two transmit and two receive antenna system baseband representation is shown in figure 2.7.For this configuration the encoding and transmission sequence of the information symbols is similar to the case of a single receiver, as given in table 4.1. Table 4.2 defines the channels between transmit and receive antennas, and Table 4.3 gives the received signal notation at the receive antennas.

Table 3.2 *The definition of channels between the transmit and receive antennas*

	Receive antenna 0	Receive antenna 1
Transmit antenna 0	h_0	h_2
Transmit antenna 1	h_1	h_3

Table 3.3 *The notation for the received signals at the tow two receive antennas*

	Receive antenna 0	Receive antenna 1
Time *t*	r_0	r_2
Time *t* + *T*	r_1	r_3

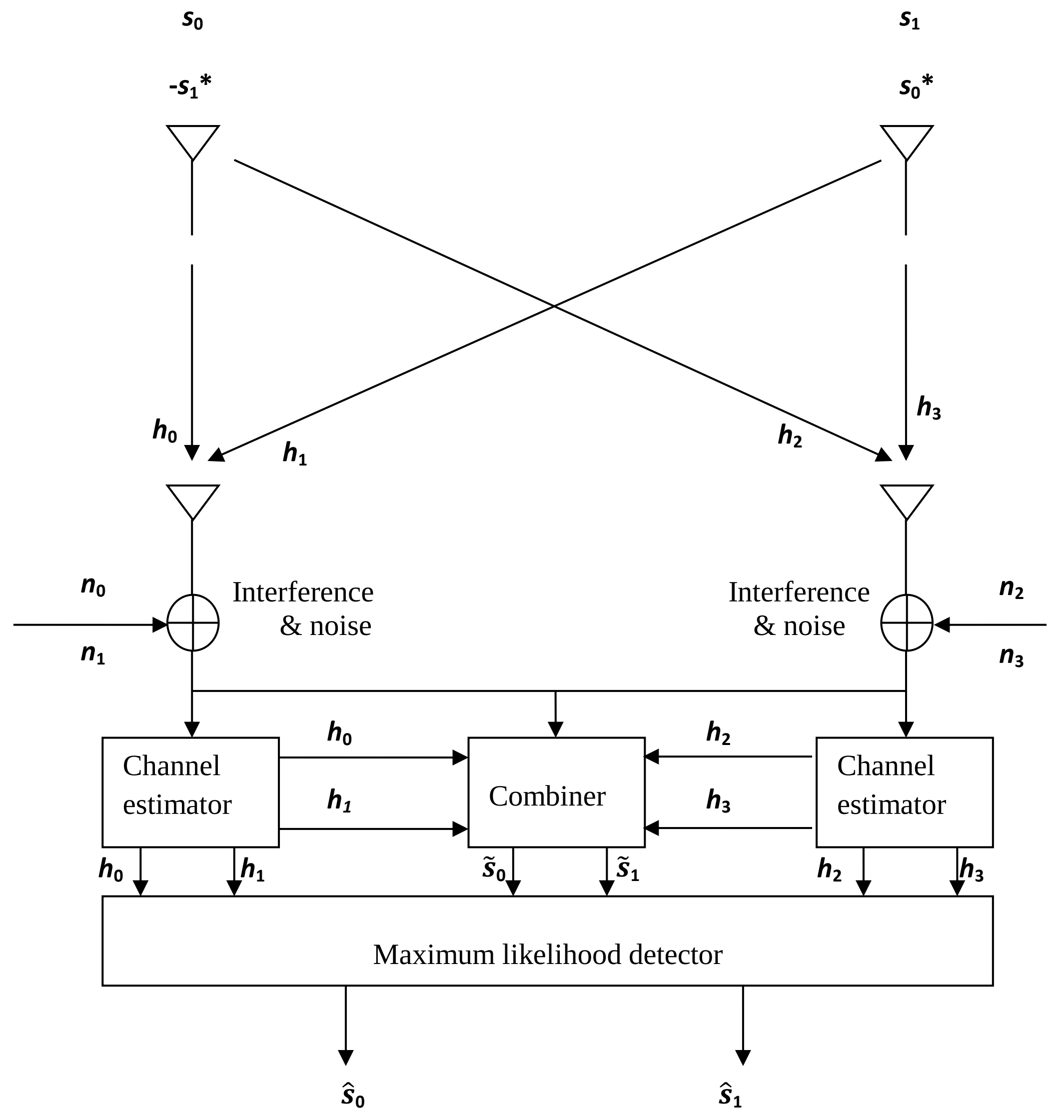

Fig 3.4 *Second order diversity scheme[8]*

The received signals at the two receivers are

$$r_0 = h_0 s_0 + h_1 s_1 + n_0 \qquad r_1 = -h_0 s_1^* + h_1 s_0^* + n_1$$

$$r_3 = h_2 s_0 + h_3 s_1 + n_2 \qquad r_4 = -h_2 s_1^* + h_3 s_0^* + n_3 \tag{3.5}$$

Receiver thermal noise and interference represented by complex random variables n_0, n_1, n_2, n_3. The combiner shown in figure combines the signals in following way which are sent to maximum likelihood detector.

$$\tilde{s}_0 = h_0^* r_0 + h_1 r_1^* + h_2^* r_2 + h_3 r_3^* \quad \text{and} \quad \tilde{s}_1 = h_1^* r_0 - h_0 r_1^* + h_3^* r_2 - h_2 r_3^* \tag{3.6}$$

On simplifying we have

$$\tilde{s}_0 = (\beta_0^2 + \beta_1^2 + \beta_2^2 + \beta_3^2)s_0 + h_0^* n_0 + h_1 n_1^* + h_2^* n_2 + h_3 n_3^*$$

$$\tilde{s}_1 = (\beta_0^2 + \beta_1^2 + \beta_2^2 + \beta_3^2)s_1 - h_0 n_1^* + h_1^* n_0 - h_2 n_3^* + h_3^* n_2 \quad (3.7)$$

These signals now sent to the decoder in which the decision criteria expressed in (3.8) or (3.9) for PSK signals.

Choose s_i if and only if

$$(\beta_0^2 + \beta_1^2 + \beta_2^2 + \beta_3^2 - 1)|s_i|^2 + d^2(\tilde{s}_0, s_i) \le (\beta_0^2 + \beta_1^2 + \beta_2^2 + \beta_3^2 - 1)|s_k|^2 + d^2(\tilde{s}_0, s_k) \quad (3.8)$$

Choose s_i if and only if

$$d^2(\tilde{s}_0, s_i) \le d^2(\tilde{s}_0, s_k), \ \forall i \ne k \quad (3.9)$$

Similarly, for s_1, using the decision rule is to choose signal s_i if and only if

$$(\beta_0^2 + \beta_1^2 + \beta_2^2 + \beta_3^2 - 1)|s_i|^2 + d^2(\tilde{s}_1, s_i) \le (\beta_0^2 + \beta_1^2 + \beta_2^2 + \beta_3^2 - 1)|s_k|^2 + d^2(\tilde{s}_1, s_k) \quad (3.10)$$

Or, PSK signlas,

Choose s_i if and only if $d^2(\tilde{s}_1, s_i) \le d^2(\tilde{s}_1, s_k), \forall i \ne k$ (3.11)

This combining scheme is similar to the case with a single receive antenna. i.e., the combined signals from the two receive antennas are the simple addition of the combined signals from each receive antenna. So we say that, to obtain the diversity order as 2*M* branch MRRC using two transmit and M receive antennas we can use the combiner for each receive antenna and then simply add. The diversity order of systems with one transmit and multiple receive antenna doubled by using two antennas at the transmitter scheme.

3.5 STC-OFDM MIMO System

Space time coding technique is an effective coding technique that uses transmit diversity to reduce the detrimental effect in wireless fading channels by combining signal processing at the receiver with effective coding techniques perfect to multiple transmit antennas to achieve higher data rates. OFDM is another promising scheme that can effectively minimize ISI induced by wireless multipath fading channels. Thus, the combination of STC and OFDM is natural and promises and enhanced in terms of signal power and spectral efficiency in wideband wireless ad-hoc channels [3].

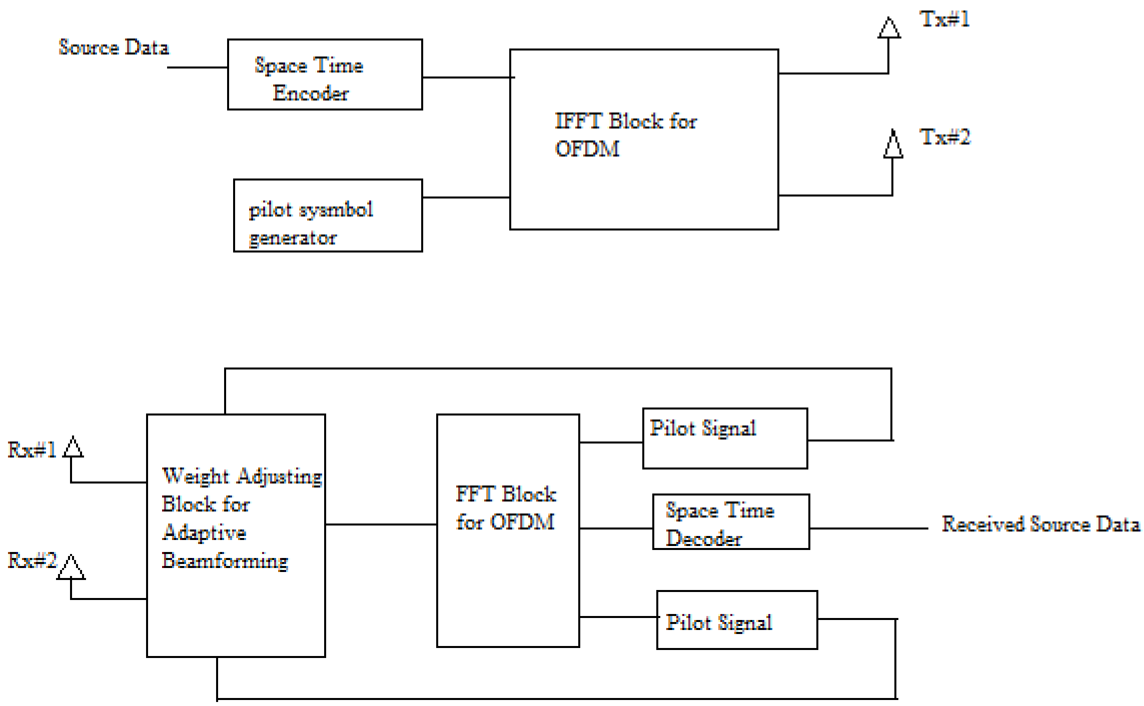

Fig 3.5 *ST coded OFDM system with CCI Cancellation(Transmitter and Receiver) [2]*

3.6 Conclusion

In this chapter we have seen that multi-antenna MIMO-OFDM technique is one the important transmission scheme in wireless communication. for more effective and high data rate wireless communication service and diversity gain, the most of the service provider are going this kind of STC MIMO-OFDM aided schemes. We conclude that, Space time coding is a very effective scheme which is used in the transmitter side for less erroneous data transmission. We also concluded that combination of STC and OFDM enhanced the quality of the high speed communication system in terms of signal power and spectral efficiency in wideband wireless ad-hoc channel.

CHAPTER 4

CO-CHANNEL INTERFERENCE IN MIMO-OFDM SYSTEM

4.1 Introduction

In this chapter we will discuss about the reason behind the co-channel interference and effect of the co-channel interference in the system performance. There are many techniques to mitigate the co-channel interference. Beamforming is one of the important techniques to mitigate co-channel interference and it is used to improve the performance of the communication system.

4.2 Co-Channel Interference

Frequency spectrum is a very important resource which is divided into non-overlapping spectrum bands, assigned to different cell in cellular mobile communication (GSM & LTE Systems). A cell means to the hexagonal or circular area around the base station antenna, in cellular mobile communications. In Frequency Reuse scheme, frequency bands are re-used. The same spectrum bands are re-assigned to other distant cells, after certain geographical distance. The co-channel interference happens in the cellular mobile wireless networks owing to this phenomenon of Frequency reuse. Thus, besides the intended signal from within the cell, signals at the same frequencies which are called co-channel signals, arrive at the receiver from the undesired transmitters which are located in far away in some other cells and become the reason for deterioration in receiver performance.

Sources of interference:

- ❖ Another user in the same cell.
- ❖ A call in progress in the neighboring cell.
- ❖ Other base stations working in the same frequency band.
- ❖ Non-cellular system leaks energy into the cellular frequency band.

To reduce co-channel interference, co-channel cell must be separated by a minimum distance.

- If the area of the cell is approximately the same
  - co-channel interference is independent of the transmitted power
  - co-channel interference is a function of
    - *R*: Radius of the cell
    - *D*: distance to the center of the nearest co-channel cell
- Increasing the ratio $Q=D/R$, *the* interference is reduced. …. (4.1)
- Q is called the co-channel reuse ratio.
- For a hexagonal geometry

$Q = \frac{D}{R} = \sqrt{3N}$,A small value of Q provides large capacity. …. (4.2)

- A large value of Q improves the transmission quality - smaller level of co-channel interference
- A tradeoff must be made between these two objectives

- Let,be the number of co-channel interfering cells. For a mobile receiver, the signal-to-interference ratio (SIR) can be expressed as:

$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i} \quad \text{….. (4.3)}$$

S: the desired signal power

I_i : Interference power caused by the *i*th interfering co-channel cell base station

- The average received power at a distance *d* from the transmitting antenna is approximated by

$$P_r = P_0\left(\frac{d}{d_0}\right)^{-n} \quad \text{or} \quad P_r(\text{dBm}) = P_0(\text{dBm}) - 10n\log\left(\frac{d}{d_0}\right) \quad \text{….. (4.4)}$$

n is the path loss exponent which ranges between 2 and 4.

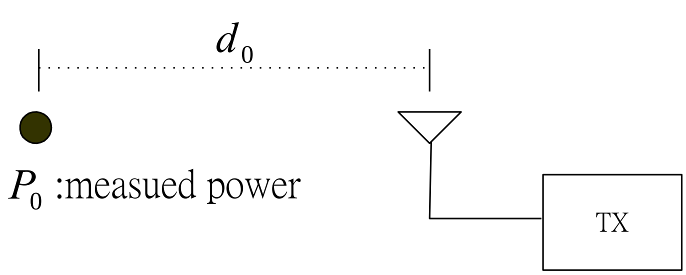

Fig 4.1 *Close-in Reference point*

When the transmission power of each base station is equal, SIR for a mobile can be approximated as : $\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}}$ .... (4.5)

- Consider only the first layer of interfering cells.

$$\frac{S}{I} = \frac{(D/R)^n}{i_0} = \frac{\left(\sqrt{3N}\right)^n}{i_0} \quad , \; i_0 = 6 \qquad \text{…. (4.6)}$$

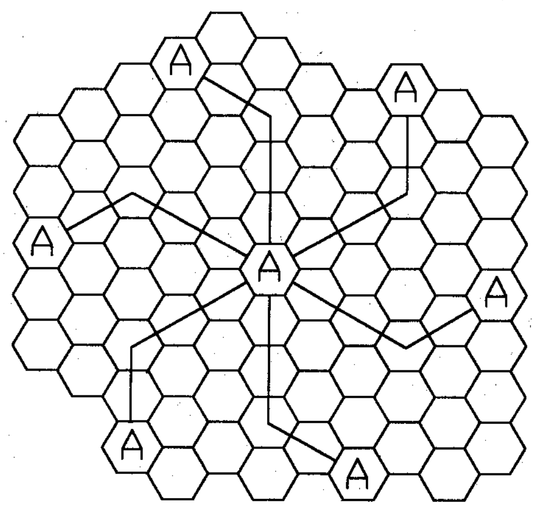

Fig 4.2 *Cell Structure for GSM mobile communication [11]*

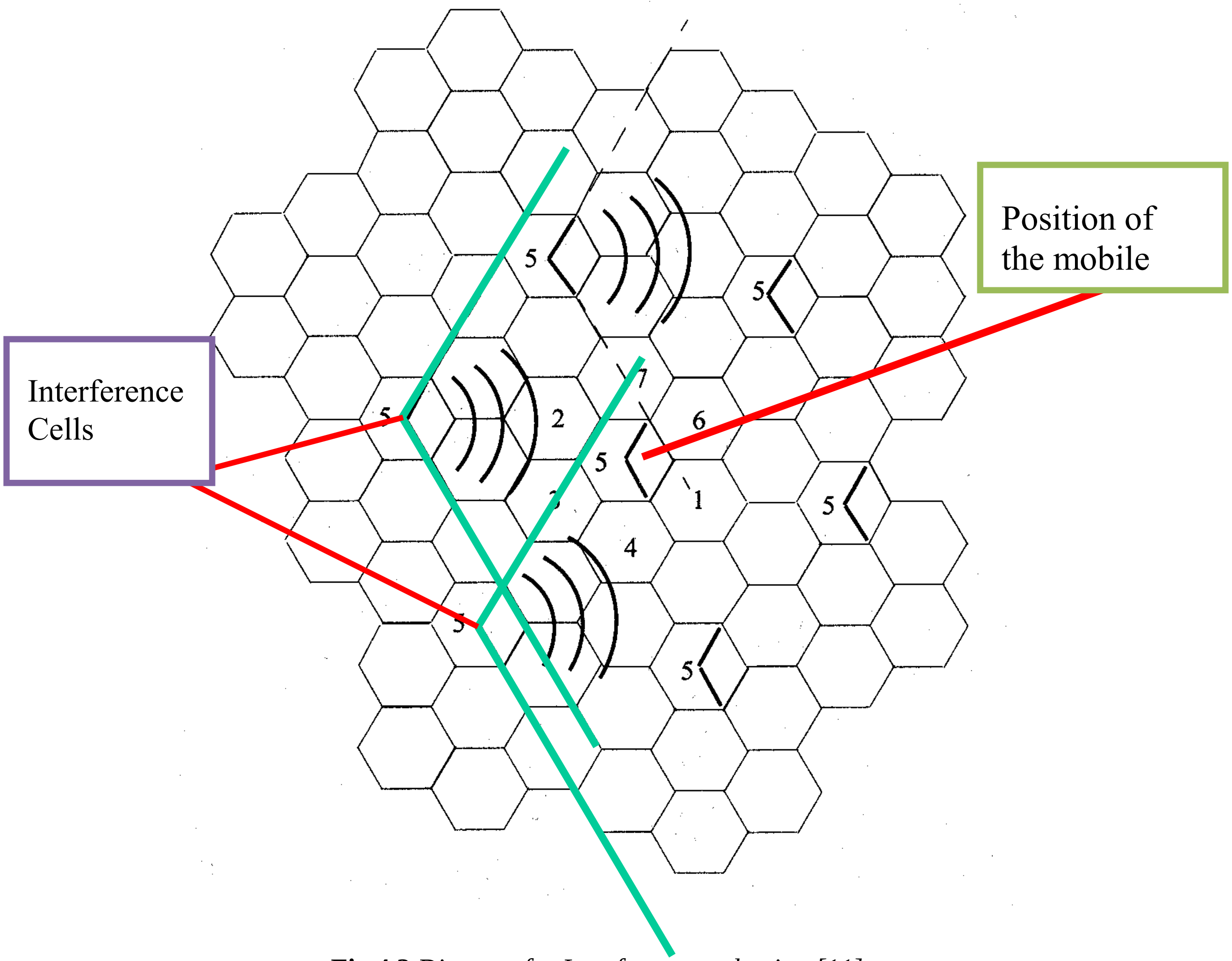

Fig 4.3 *Diagram for Interference reduction [11]*

4.3 Beamforming Technique

Beamforming which is also called spatial filtering, is a signal processing technique used in sensor antenna arrays for directional signal transmission or reception. This beamforming is achieved by combining elements in a phased antenna array in such a way that signals at particular angles face a constructive interference while others face destructive interference. To achieve spatial selectivity and to mitigate co-channel interference in MIMO-OFDM communication system, beamforming can be used at both the transmitting and receiving ends of the communication system. The improvement by beamforming compared with omnidirectional reception or transmission is known as the receive or transmit gain (or loss).

Beamforming can be used for radio or other waves also. It has found many applications in radar, sonar, wireless communications, acoustics, and biomedicine

There are several beamforming techniques like null-steering beamforming, frequency domain beamforming,LMS style beamforming, RLS style beamforming techniques. Beamforming is very effective technique to mitigate the co-channel interference.

4.4 Mathematical Expression of Co-Channel Interference and CCI Cancellation

In this section, we will discuss about the effect of CCI in MIMO-OFDM communication system mathematically[3] and by simulation also. We will use also discuss about the beamforming technique to mitigate CCI in STC_OFDM communication system.

Data Sequence= x_t^i …. (4.7)

Resulting signal after IFFT: $y_t^i = F^H x_t^i$ …. (4.8)

IFFT Matrix: F …..(4.9)

Two independent paths in each DOA: $h_p = \left[h_p^1 \, h_p^2 \right]$ p =1,2 ....(4.10)

The received signal at the antenna array:

$$V_t = \sum_{p=1}^{2} a(\theta_p) h_p y + \sum_{p=1}^{2} a(\theta_{p,CCI)} h_{p,CCI} Z_t + N_t$$ ….(4.11)

Antenna array response steering in the direction of arrival

$\theta_p =$ $a(\theta_p) = \left[1.....e^{-j(n_R - 1)\sin\theta_p} \right]^T$ ….(4.12)

The lth beamformer output at time t : $r_t^l = (W_t^l)^H V$ ....(4.13)

The received signal vector in frequency domain: $Y_t^l = F(r_t^l)^H$ ….(4.14)

The weight vector of the l[th] beamformer at time t is adjusted by the following recursive relation:

$$W_{t+1}^{l} = W_t^l + 2\mu V_t F_Q^H (y_{t,Q}^l - Y_{t,Q}^l)$$ ...(4.15)

The Beam response: $b^l(\theta) = (W^l)^H a(\theta)$ ..(4.16)

The beam response matrix= D ..(4.17)

Beam response with imposed null :

1) $b_{null}^l(\theta_n) = 0$ for $(\theta_d - \Delta\theta_d / 2) \le \theta_n \le (\theta_d + \Delta\theta_d / 2)$ …(4.18)

2) $b_{null}^l(\theta_n) = b^l(\theta_n)$ elsewhere for $n = 1,.....,N$ ...(4.19)

Weight vector for null synthesis : $W_{null}^l = D^{-1} b_{null}^l(\theta_n)$ ....(4.20)

Output of the beamformer: $r_t^l = h_t Y + (W_t^l)^H N_t$ …(4.21)

4.5 Adaptive Beamforming and Null Steering Beamforming

Adaptive beamforming is LMS style beamforming which used pilot symbol as to get feedback to the weight vector block to update the weight vector co-efficient adaptively to get more perfect result by mitigating co-channel interference. In null steering beamforming, the main signal beam is steered according to receiver antenna position. The comparison analysis between the adaptive beamforming and null steering beamforming will be given in the simulation chapter.

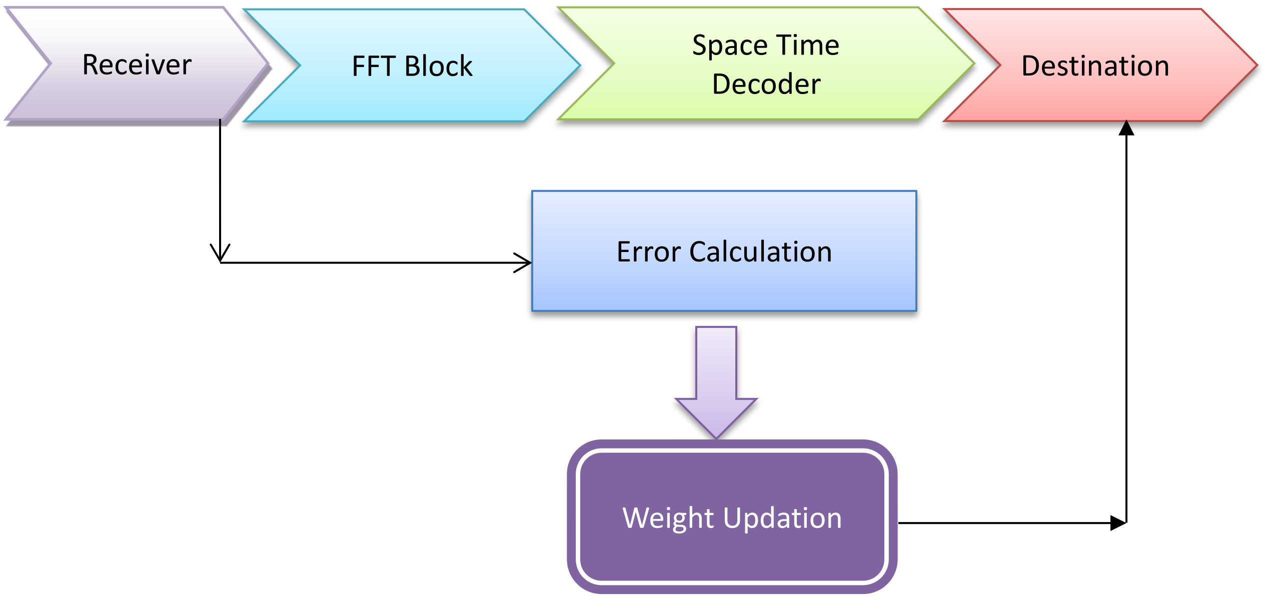

Fig 4.4 *Algorithm for Beamforming to mitigate CCI in STC-OFDM MIMO system[2]*

4.6 Conclusion

The effect of co-channel interference in wireless communication system and basic concept is discussed in this chapter. We also went through the mathematical formulas which relate the cause of the co-channel interference and cell structure of the GSM cellular mobile communication. We will discuss about the process of applying LMS style beamforming to mitigate co-channel interference in STC-OFDM MIMO system in the next chapter by some simulation process. We can also conclude that beamforming can be one of the effective techniques to mitigate the co-channel interference in wireless communication system.

CHAPTER 5

SIMULATION STUDY, RESULTS AND DISCUSSION

5.1 Introduction

In this chapter, the system model of the STC MIMO-OFDM communication system is shown. The block diagram for adaptive beamforming technique is also shown consequently

Effect of co-channel interference in this system also has been shown. Beamforming technique is one of the effective technique to mitigate co-channel interference. The performance of several beamforming techniques is also shown through simulation.

5.2 Block Diagram of Transmitter and Receiver of STC MIMO-OFDM system

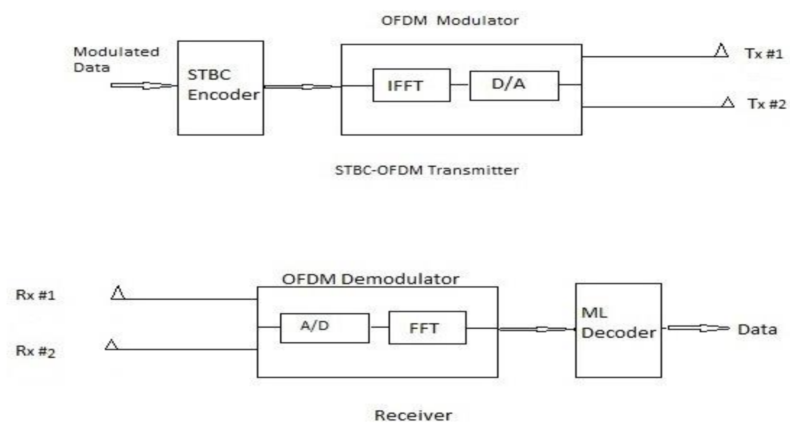

Fig 5.1 *Block Diagram of Transmitter and Receiver(Conventional STC MIMO-OFDM system)*

5.3 Block Diagram of The System model for Adaptive Beamforming Technique

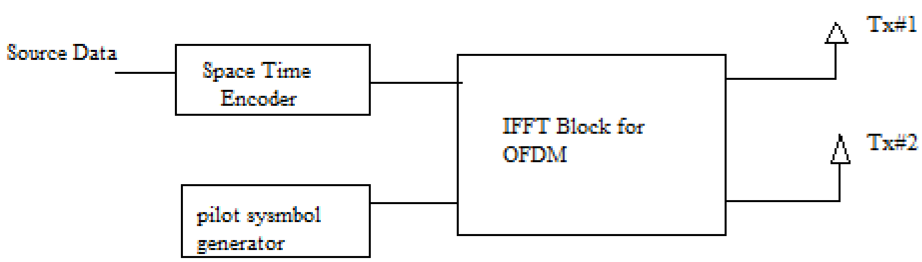

Fig 5.2 *Block Diagram of Transmitter (STC MIMO-OFDM system)*

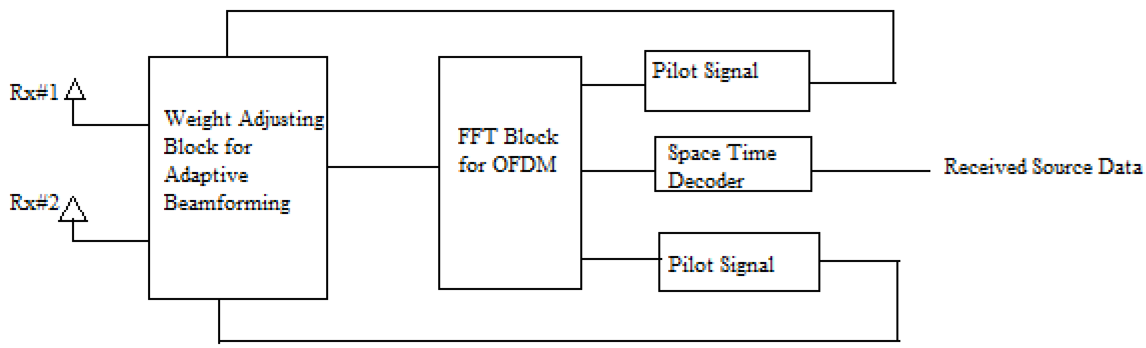

Fig 5.3 *Block Diagram of STC MIMO-OFDM Receiver with CCI canceller(Adaptive Beamforming)*

This block diagrams depicts the system model for CCI cancellation using adaptive beamforming technique. The weight vector block in receiver side is adjusted through feedback process. The performance analysis of the STC MIMO-OFDM communication system has been done in the consequent part.

5.4 Table for Simulation Parameters

Modulation	BPSK, QPSK
Channel	Rayleigh fading channel, AWGN channel
Number of Carriers	256,1024
Number of Frames	1000
Transmitting Antennas	2
Receiving Antennas	2
SNR Range	0 dB to 20 dB
SIR values	5 dB, 10 dB, 15 dB

Table 5.1 *Table for Simulation Parameters*

For simulation process the above parameters are considered for analysis of the performance of the system. For the simulation process, BPSK, QPSK modulation technique is used to transmit the data.2X2 MIMO-OFDM system is used with Space Time Encoder and Decoder.

5.5 Study of STC MIMO-OFDM system

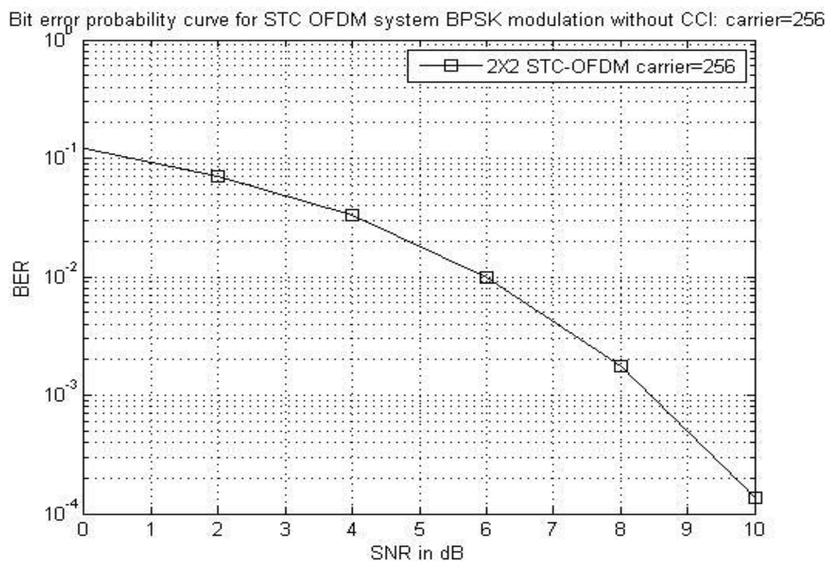

Fig.5.4 *BER Vs. SNR Graph for STC MIMO-OFDM system (BPSK modulation, Carrier=256)*

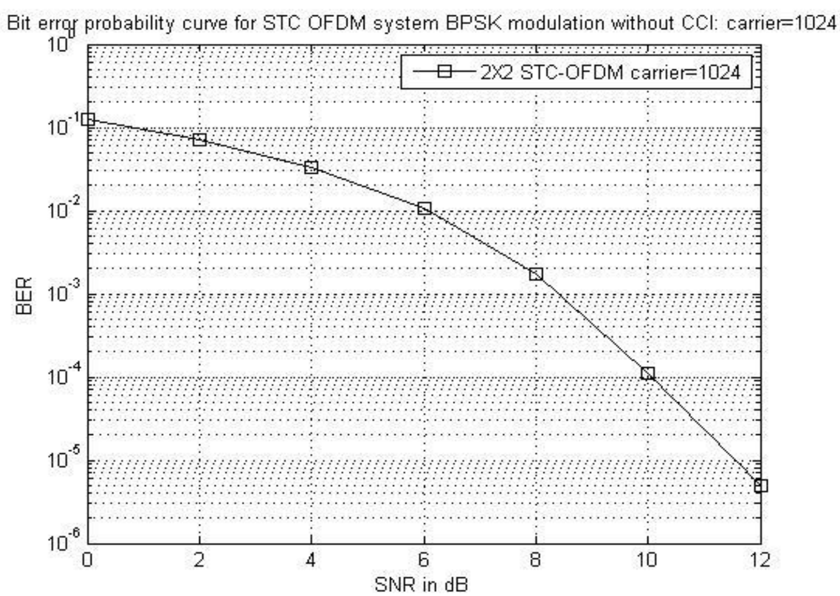

Fig.5.5 *BER Vs. SNR Graph for STC MIMO-OFDM system (BPSK modulation, Carrier=1024)*

This graphs depicts that for different number of sub-carriers, the system performs mostly same. As more number of sub-carriers add more complexity to the transmission process, so most of the simulation processes are done considering 256 sub-carriers.

5.6 Effect of Co-Channel Interference in STC MIMO-OFDM system

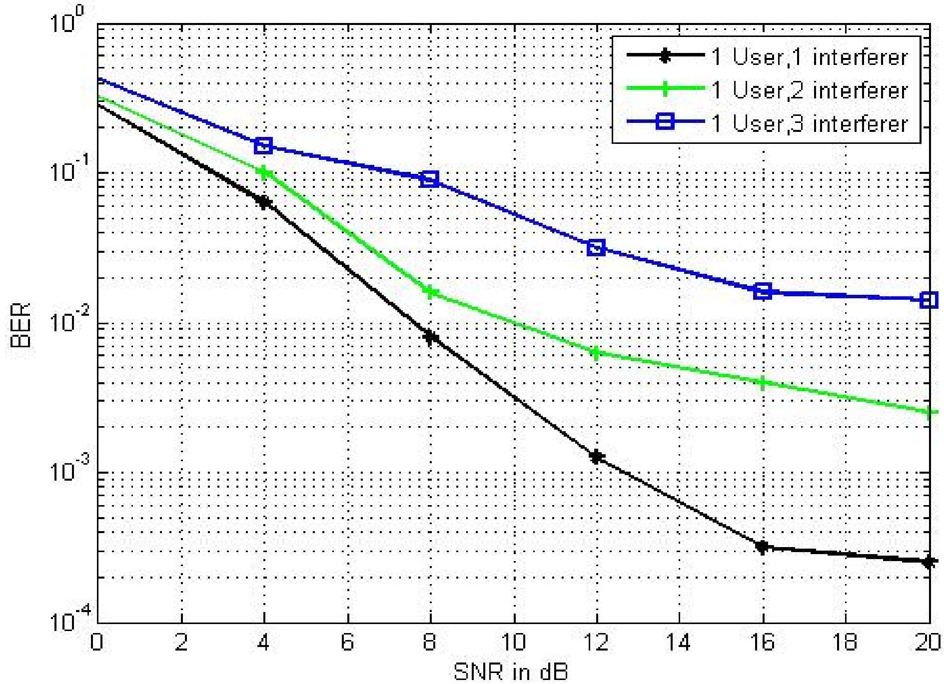

Fig.5.6 *Effect of CCI in STC MIMO-OFDM system (BPSK modulation)*

In this simulation graph, the effect of co-channel interference on the STC MIMO-OFDM communication system is shown. Different numbers of interfering users has been introduced with the main user. Because of co-channel interference due to interfering users, the performance of the system degraded. There are several techniques to mitigate the CCI effect. Beamforming technique is one of the effective techniques to mitigate CCI effect.

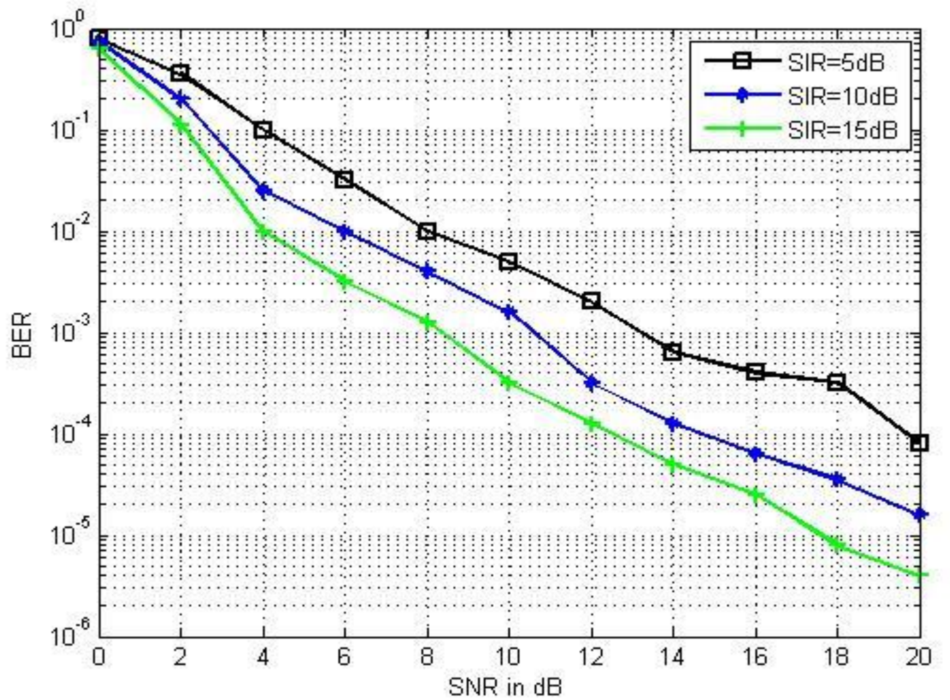

Fig.5.7 *Performance curve for different SIR values in STC MIMO-OFDM system (BPSK modulation)*

This simulation result gives performance graph for different SIR values. SIR depicts the Signal to Interference ratio. For higher SIR value the performance of the system more improved as due to the increased signal power and system become more immune to the interference.

5.7 LMS style Beamforming to mitigate Co-Channel Interference in STC MIMO-OFDM system

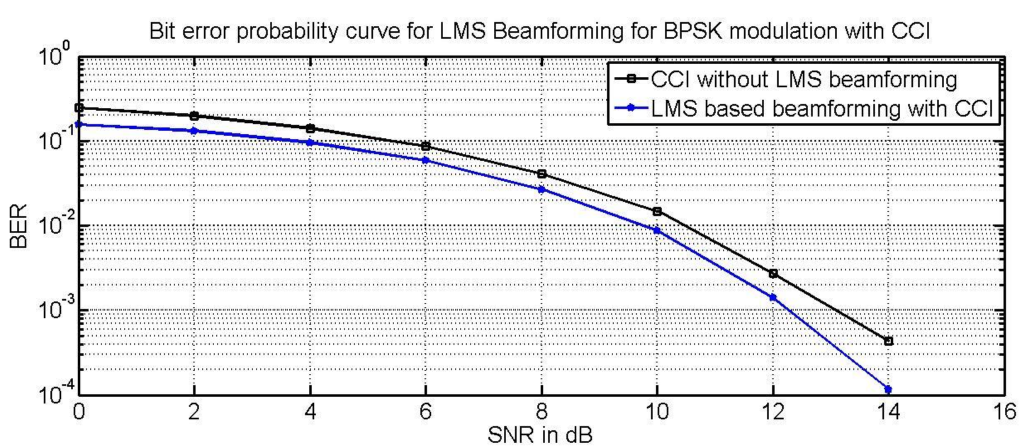

Fig.5.8 *CCI cancellation using LMS style beamforming(STC-OFDM system,BPSK)*

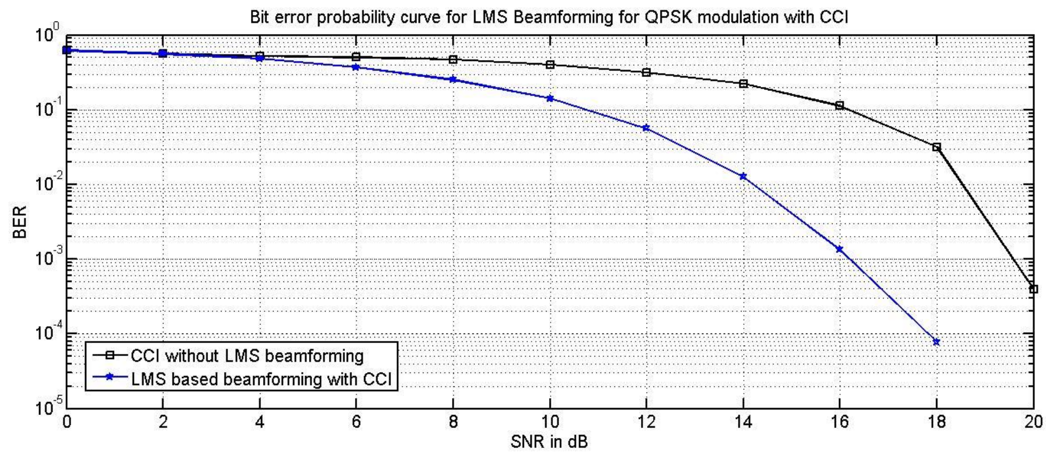

Fig.5.9 *CCI cancellation using LMS style beamforming(STC-OFDM system,QPSK)*

These simulation result gives the basic idea about the performance of the STC-OFDM system with the application of LMS style beamforming to mitigate the co-channel interference for BPSK,QPSK modulation scheme.

5.8 Adaptive Beamforming and Null steering Beamforming

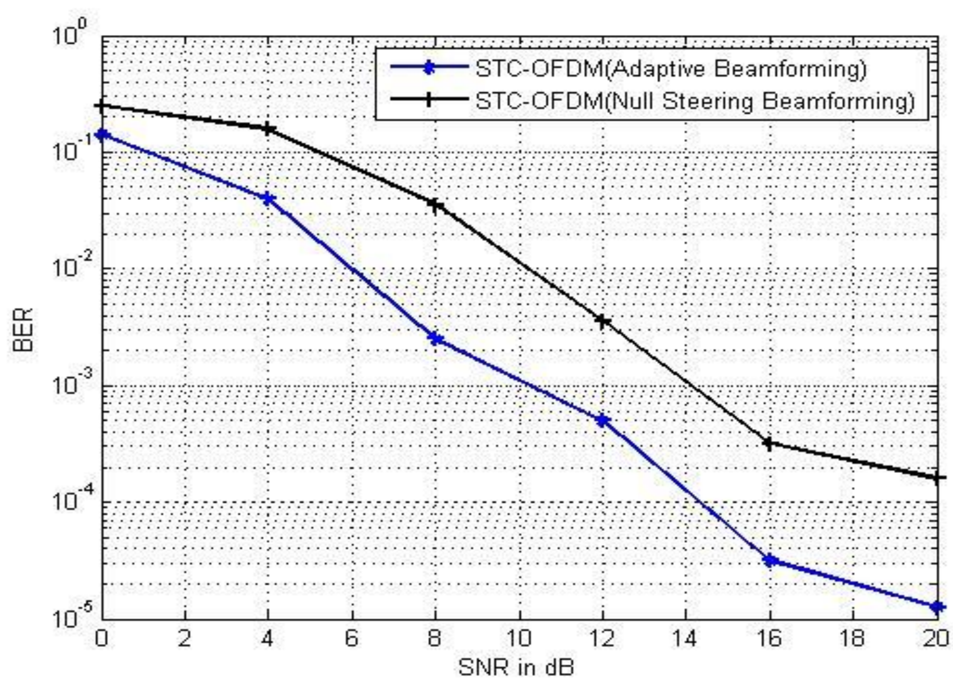

Fig.5.10 *BER comparison of the STC-OFDM using the adaptive beamforming and the null steering beamforming*

Adaptive beamforming technique outperforms the method based on the null steering beamforming method. In this adaptive beamforming technique, the weight vector is updated adaptively to get the optimum result using feedback method.

5.9 Conclusion

From this chapter we can conclude STC-OFDM MIMO system model can be a very effective system model for new generation communication system. Now a days, co-channel interference also a very important concern for efficient high speed communication service. LMS style beamforming can be an effective technique to mitigate the co-channel interference in STC MIMO-OFDM communication system. Adaptive beamforming with null deepening performs better than null steering beamforming. LMS algorithm plays very important role in CCI cancellation.

CHAPTER 6

CONCLUSION

AND

FUTURE SCOPE OF WORK

CONCLUSION AND FUTURE SCOPE OF WORK

The combination of MIMO OFDM system is one of the effective ways to combat the fading effect of the channel and to conserve the bandwidth. Further, we can say that the spatial diversity schemes are plays major role in retaining the data quality at the receiver end from channel interference. OFDM itself changes the frequency selective channel into several parallel flat fading channels which helps to mitigate the inter symbol interference. The combination of STC and OFDM enhanced the quality of the high speed communication system in terms of signal power and spectral efficiency in wideband wireless ad-hoc channel. Space time coding provides diversity gain to the communication system for more efficient high speed data transmission. STC-OFDM MIMO system model can be a very effective system model for new generation wireless communication. Now a days, co-channel interference also a very important concern for efficient high speed communication service. LMS style beamforming can be an effective technique to mitigate the co-channel interference in several communication systems. Adaptive beamforming technique with null deepening outperforms the method based on null steering beamforming.

There is a great future scope on this project as the MIMO-OFDM schemes are integral part of the modern high speed communication system. Several new technology like neural network based beamforming techniques can be developed for the more effective, efficient and high speed wireless communication.

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